Introduction to Radioastronomy:

Instrumentation

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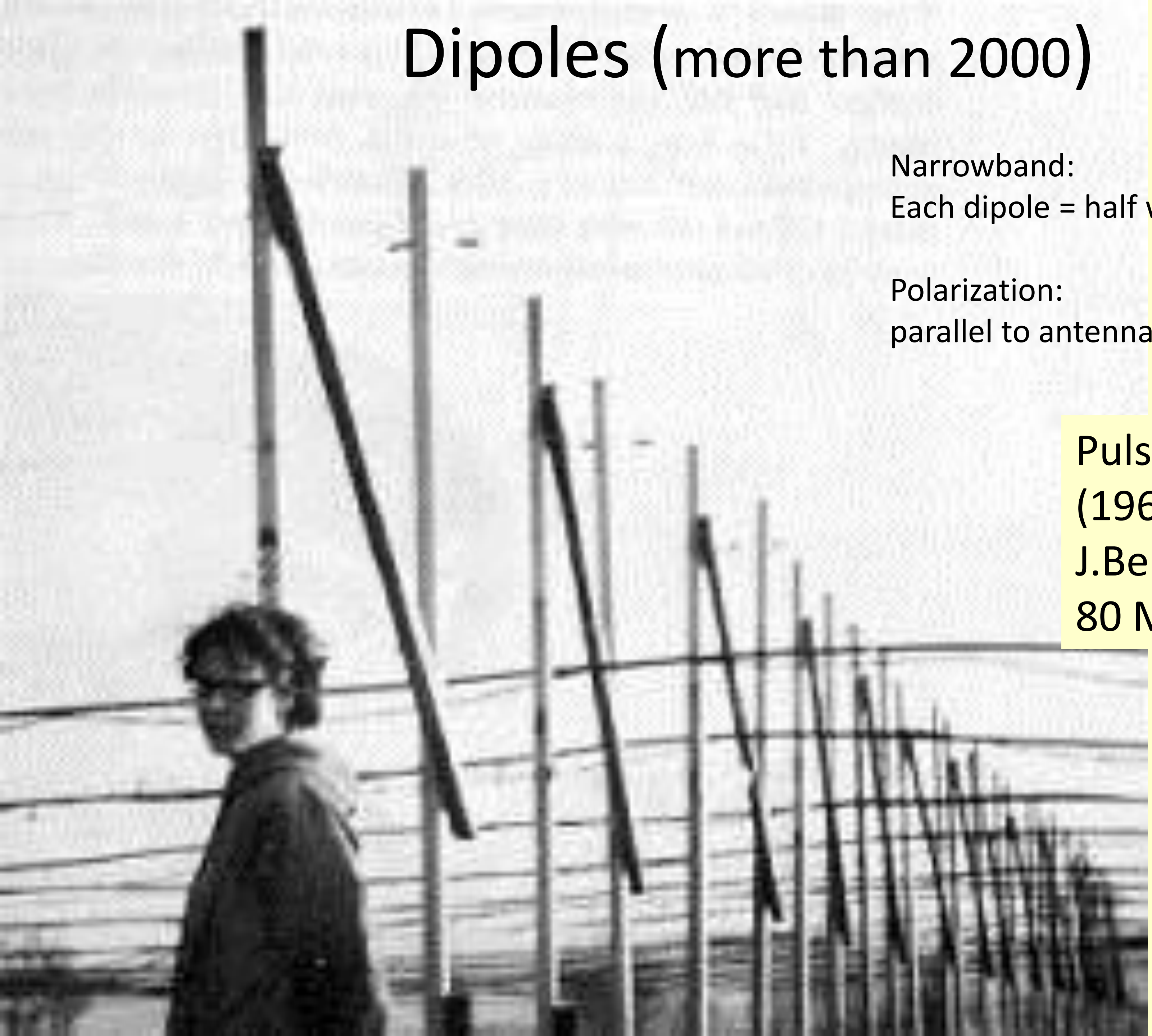
http://astro.u-strasbg.fr/~koppen/JKHome.html

Instrumentation

- Antenna
- Receiver
- Data processing

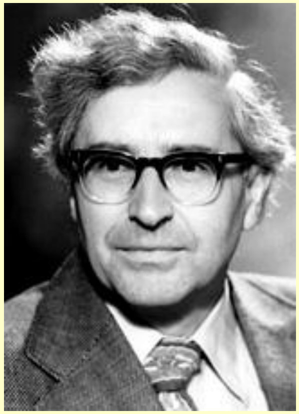
Dipoles (more than 2000)



Narrowband:
Each dipole = half wavelength

Polarization:
parallel to antenna

Pulsars
(1967,
J.Bell-Burnell,
80 MHz)

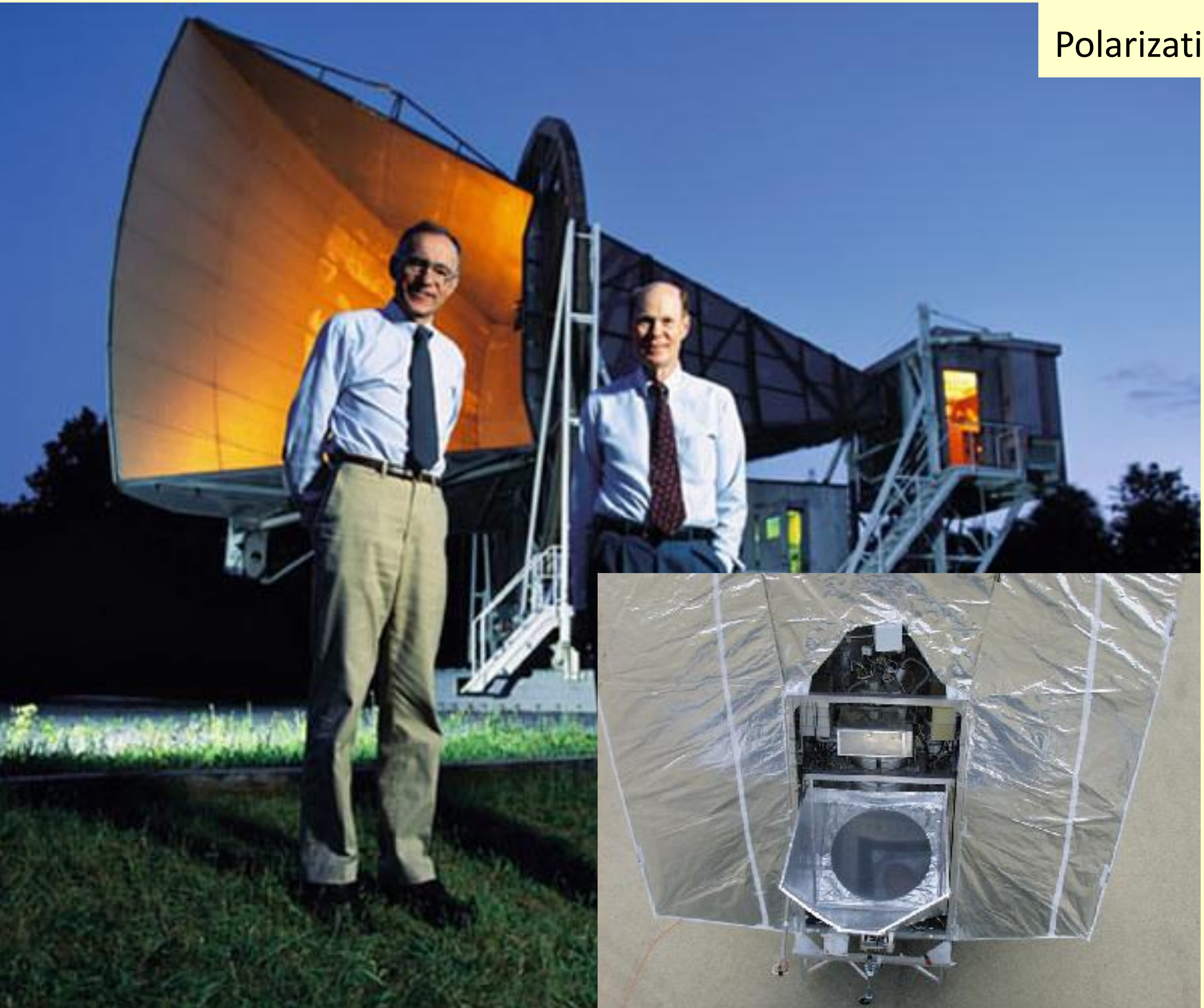


A.Hewish

Horn antenna

Broadband, needs to
be larger than wavelength

Polarization parall. to side



3K cosmic microwave background, the left-over from the BigBang

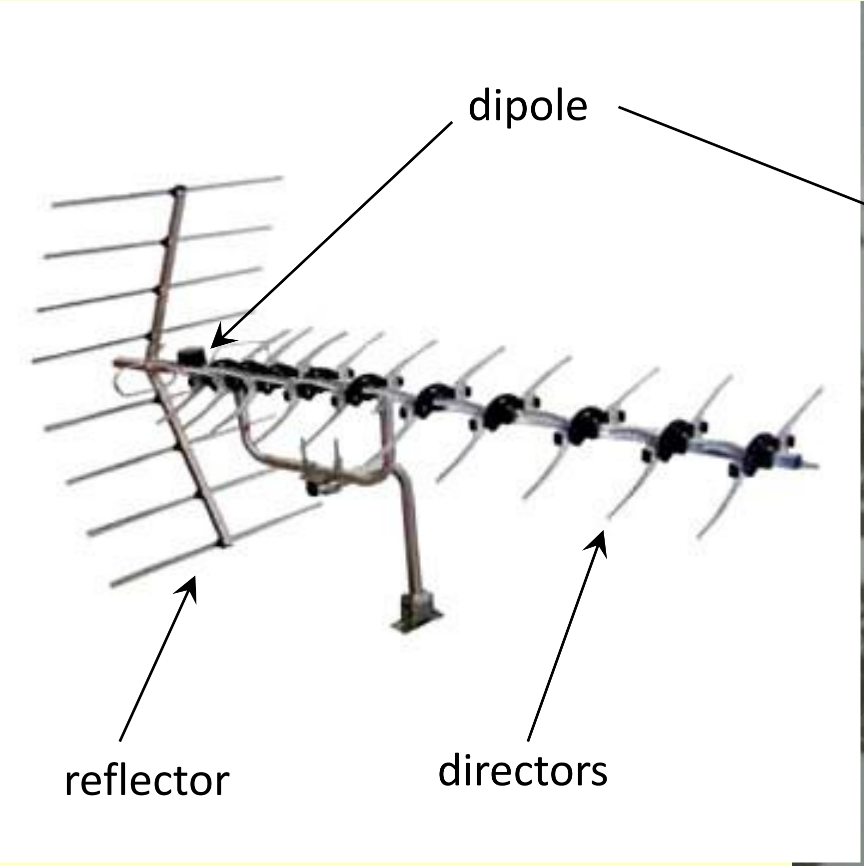
(1965, A.Penzias & R.Wilson, 4.1 GHz)

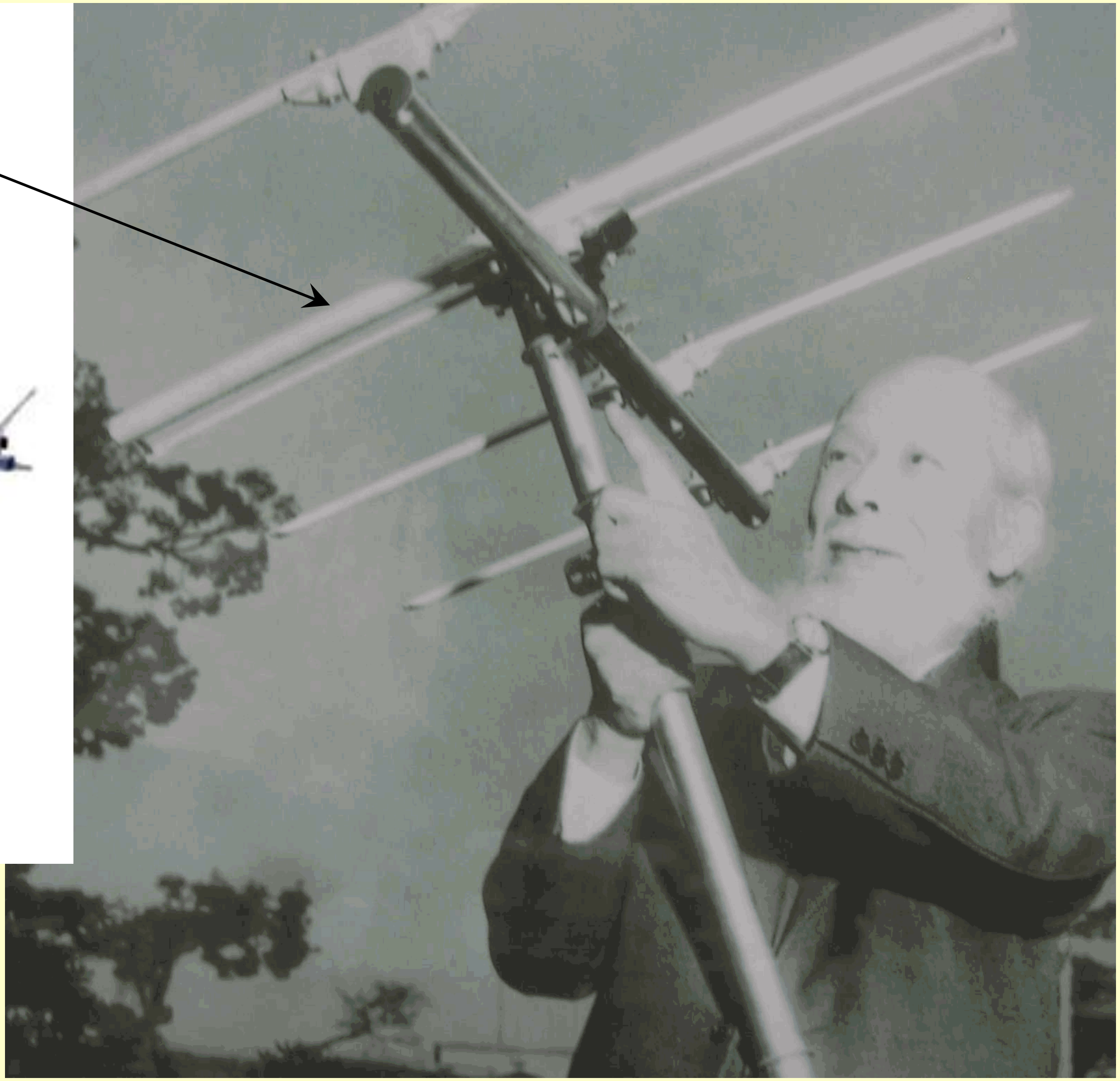
Now one does it
on 150 GHz
In Antarctica …

Yagi-Uda antenna

Narrow-band,
Width = half wavelength
Length = anything

Polarization parall.to dipole



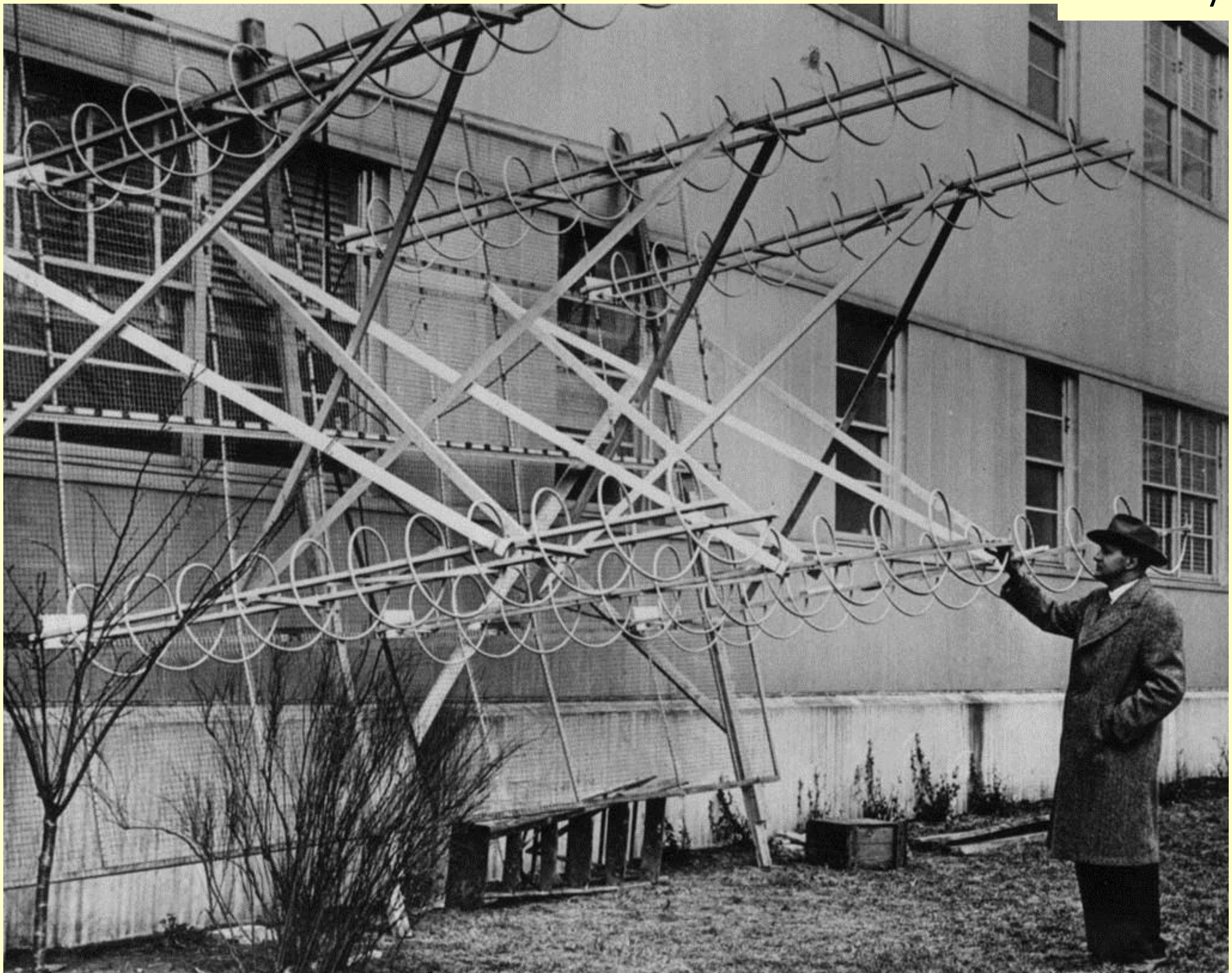


S.Uda 1926…1929
H.Yagi 1928 ➔

Helix antenna (Array)

Moderately broad-band,
circumference = wavelength

Circularly polarized



1952,
John Kraus,
W8JK,
320 MHz

WW II: 'Würzburg Giant' 7.5 m

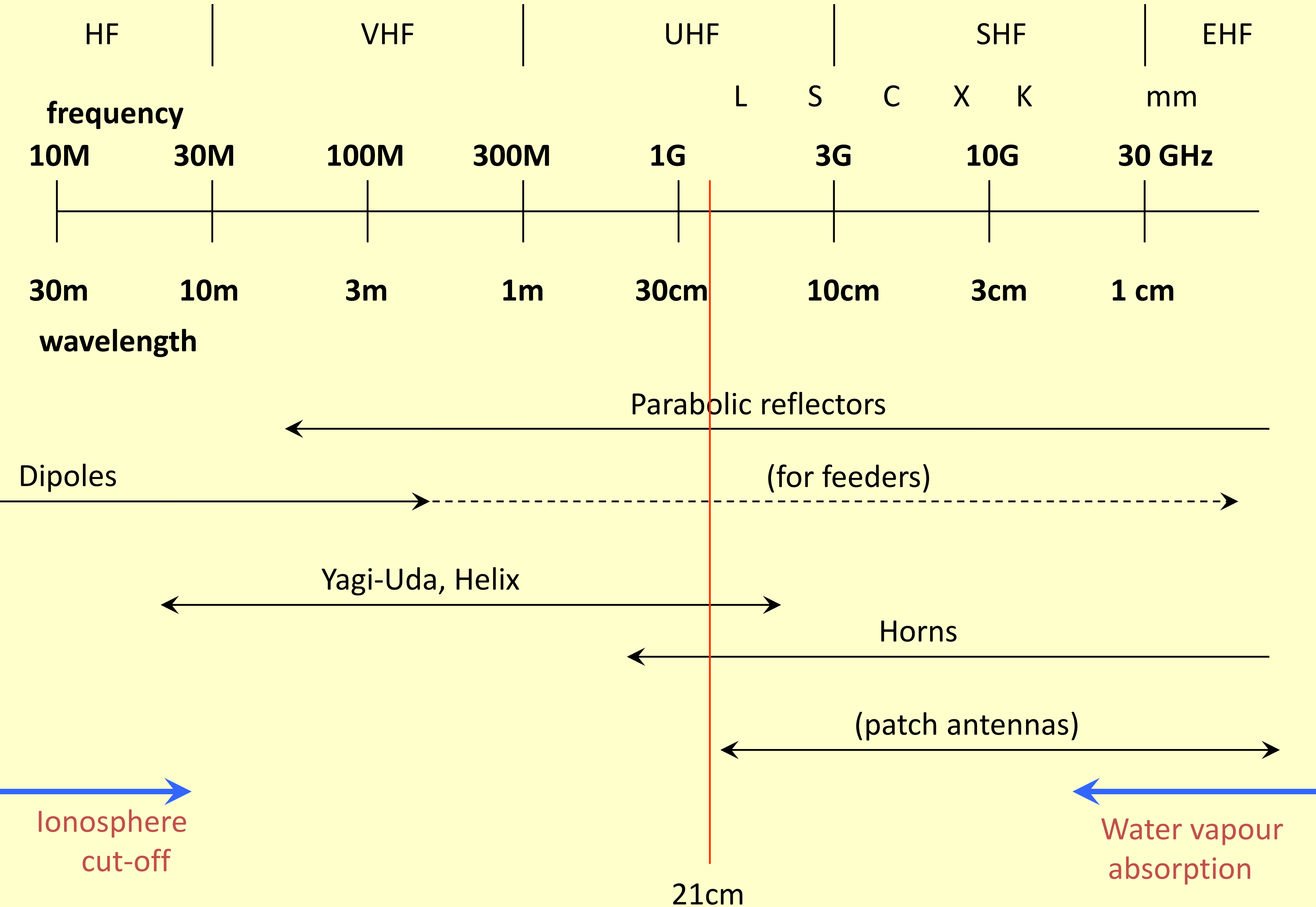
Parabolic dishes

wideband,
diam. > 10 λ
surface acc. < $\lambda/10$
holes < $\lambda/10$

2007 ISU: ESA-Dresden 1.2 m

1956 Jodrell Bank 75m

2009 ISU: ESA-Haystack 2.3 m


HF
VHF
UHF
SHF
EHF
L
S
C
X
K
mm
frequency
10M
30M
100M
300M
1G
3G
10G
30 GHz
30m
10m
3m
1m
30cm
10cm
3cm
1 cm
wavelength
Parabolic reflectors
Dipoles
(for feeders)
Yagi-Uda, Helix
Horns
(patch antennas)
Ionosphere cut-off
Water vapour absorption
21cm

Angular resolution of an antenna

- Diffraction limit: to distinguish two point objects with an instrument of aperture diametre D at wavelength λ, they must be separated by an angle larger than

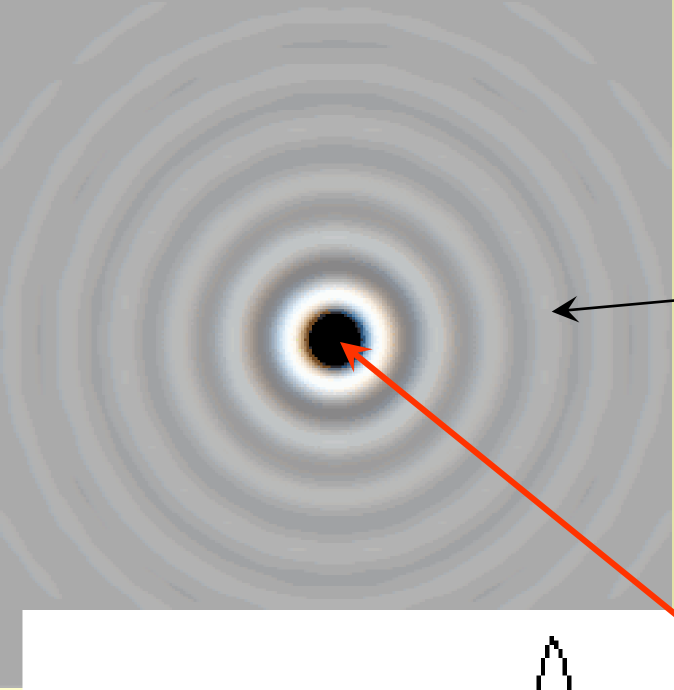
$$\sin \alpha > 1.22\ \lambda/D$$

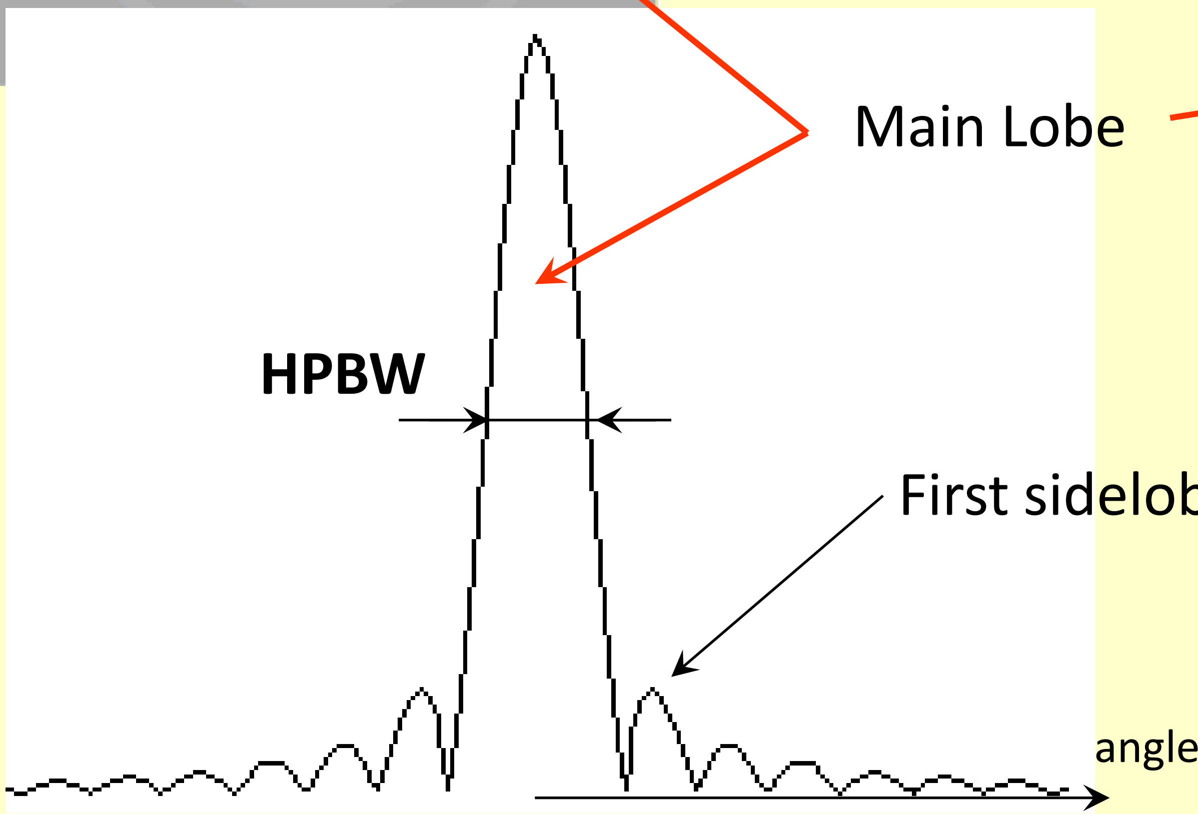
	diametre	wavelength	resolution
Human eye	2 mm	500 nm	50 arcsec
ESA-Dresden	120 cm	3 cm	1.5 deg
Arecibo	300 m	21 cm	2 arcmin
Effelsberg	100 m	3 cm	1 arcmin

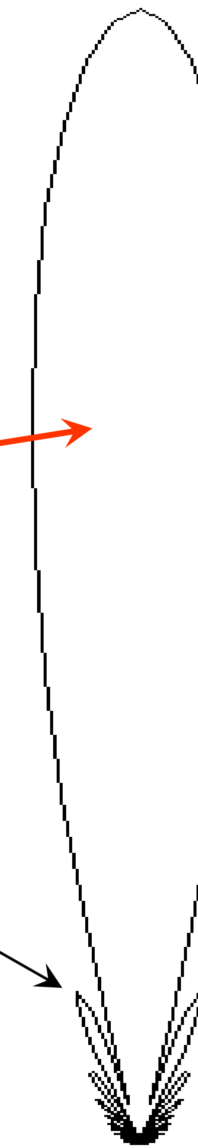
In detail: Antenna pattern

= its angular sensitivity curve

= is the interference pattern of its aperture







Half **P**ower **B**eam **W**idth

- is the angular width of the main lobe of the antenna beam – measured at half power
- Circular parabolic dish:
  - **HPBW** ≈ 58° / (D/λ)
  - **B**eam**W**idthbetween**F**irst**N**ulls ≈ 140° / (D/λ)
- Use this formula, if you know no details!

- Equivalent: Solid angle of the main beam (universal relation): $\Omega = \lambda^2 / A_{eff}$

(A_{eff} = efficiency * geometrical area)

Reciprocity

The antenna pattern is the same for receiving and for transmitting

Antenna (pattern) Gain

- As the main lobe's solid angle Ω is a fraction of the full sphere 4π, we define

  $$G = 4\pi/\Omega$$

- This quantity is thus a measure of the directivity of the antenna.
- usually given in decibels: dBi, i.e. with ref. to an isotropic antenna: $10 \log(G)$

Power received by antenna

- Flux from source: F [W/m^{2}Hz]

  convenient: Jansky 1 Jy = 10^{-26} W/m^{2}Hz
- $P = A_{eff} * F$ ➔ large antennas are sensitive

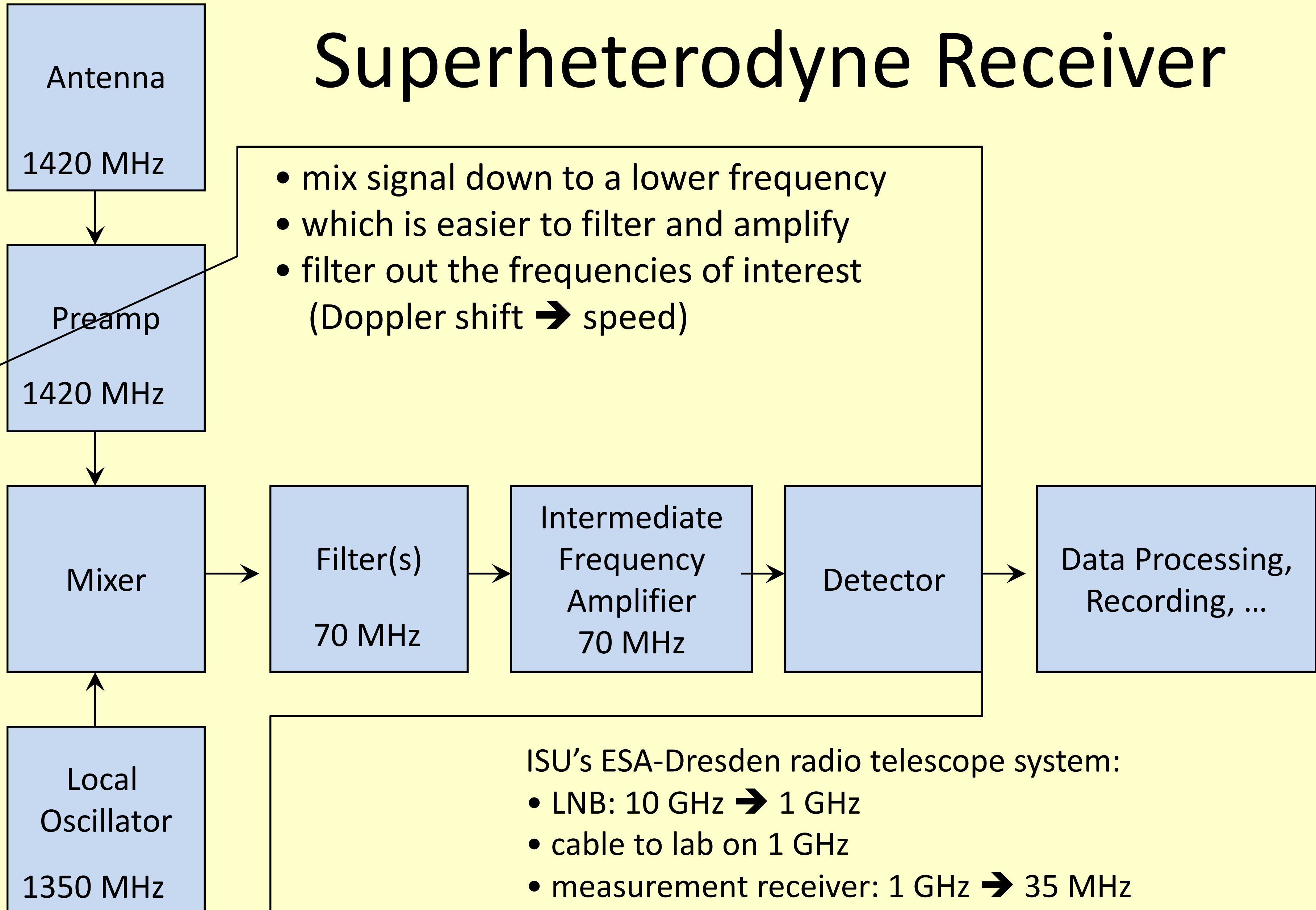
Useful relations:

- $A_{eff}/\lambda^2 = \Omega = G/4\pi$
- $HPBW = 180°/\sqrt{G} = 180°/\sqrt{4\pi\Omega}$
- ➔ high gain antennas are large and have narrow beams

Examples

	ESA-Dresden	ESA-Haystack
f [MHz] λ	11000 3 cm	1420 21 cm
Diameter [m]	1.2	2.3
Aeff [m²]	0.9	3.6
Gain [dBi]	+42	+30
HPBW [°]	1.4	5.7
Ω [sr]	0.00079	0.013
min.Flux [Jy]	50000	10000

Superheterodyne Receiver



- mix signal down to a lower frequency
- which is easier to filter and amplify
- filter out the frequencies of interest
  (Doppler shift → speed)

ISU's ESA-Dresden radio telescope system:

- LNB: 10 GHz → 1 GHz
- cable to lab on 1 GHz
- measurement receiver: 1 GHz → 35 MHz
- output to computer

(Completely) Digital Receiver

Conversion of analog signal to digital data:

- sample frequency > 2*bandwidth (Nyquist criterion)